THE

CROONIAN LECTURE,

ON

THE ADJUSTMENT OF THE EYE TO SEE OBJECTS AT DIFFERENT DISTANCES.

BY

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FROM THE

PHILOSOPHICAL TRANSACTIONS.

THE

CROONIAN LECTURE

ON

MUSCULAR MOTION.

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In the Croonian Lecture which I had the honour of laying before this learned Society last year, I endeavoured to prove, that the adjustment of the eye to different distances could take place independent of the crystalline lens; and when this was the case, it appeared to arise from a change in the curvature of the cornea.

I propose in the present lecture to prosecute the inquiry; and it will be found in this, as well as in the former, that I have received the most essential assistance from Mr. Ramsden, who continues to interest himself in the investigation, and has made all the optical experiments.

As this was a new mode of explaining the adjustment of the eye, and differed from the theories that have been previously formed upon the subject, it was thought right to consider it with caution, to pay attention to all the objections that could

be made to it, and to put it to the test of such experiments as appeared likely to refute or confirm our former observations.

It readily suggested itself, that if the convexity of the cornea was increased to a certain degree, it could be measured by means of an image reflected from its surface, and viewed in an achromatic microscope with a divided eye-glass micrometer.

To ascertain whether the quantity of increase of the convexity of the cornea, in the adjustment of the eye, could in this way be ascertained, the following experiments were contrived, and made by Mr. RAMSDEN.

Our former experiments had sufficiently proved the unsteadiness of the human eye; the first trials on the present occasion were therefore made upon convex mirrors, as these artificial corneas could be more readily managed, and such previous experiments would enable us to apply the same instruments with more facility to the eye itself.

Two convex mirrors, one $\frac{4}{10}$ of an inch focus, the other $\frac{5}{10}$, had their flat surfaces made rough, and blacked, to prevent an image being seen from both surfaces, which was found to be the case when this precaution was omitted. One of these mirrors was stuck upon a piece of wood directly opposite to a window, at twelve feet distance from it; a board, three feet long, and six inches broad, was placed perpendicularly against the sash of the window, and its image reflected from the mirror upon the object-glass of an achromatic microscope, with a divided eye-glass micrometer.

The two images were separated by means of the divided eye-glass, till their surface of contact, which appears like a black line, was rendered as small as possible. When this effect was produced on the images from the mirror of $\frac{4}{10}$ of an

inch focus, that mirror was removed, and the other put in its place; the contact of the two images, which before appeared like a line, had now acquired considerable breadth; corresponding exactly to the difference between the convexities of the mirrors.

Having in this way made trial of the instruments, and arranged all the necessary circumstances, the head of a person was so placed as to bring the eye into the same situation as the mirror, and made steady by the apparatus described in our former experiments. Under these circumstances the image reflected from the cornea was measured by the micrometer.

Mr. Ramsden made an experiment with this instrument upon my eye. In the first trials, when the eye was fresh, there was a perceptible change in the micrometer, but extremely small; this was not, however, seen afterwards, and the eye very soon became so much fatigued that it was necessary to desist. He found that every time the eye adapted itself to different distances, it was necessary to move the object-glass of the microscope further from, or nearer to, the cornea.

This experiment was repeated on four different days; and in each experiment, on the first trial, the result was a change in the micrometer, but in all the subsequent trials it could not be detected. We were induced to conclude, that the effect on the micrometer might arise from the head being moved forwards, as we found, in making experiments with the mirror, that this effect could be produced by such motion; but had it arisen from that cause, it should more frequently have occurred, and rather after the head and eye were tired, than on the first trials. It was supposed to arise from the action of the muscles of the head, but that should have produced a contrary

appearance. The effect produced on the micrometer, therefore, did not seem to depend upon external circumstances, but to arise from a change in the cornea; it was, however, too small to admit of any conclusions being drawn from it.

The same experiment was made upon several young persons; but we found it necessary, that whoever was the subject of the experiment should understand perfectly what was meant to be done, otherwise the conclusions could not be depended on; for if the eye does not see the near object with a very defined outline, it is not accurately adjusted to it; and the length of time they kept their eye upon the near object without making any complaint of being fatigued, was greater, we knew, from our own observation, than it was possible to do it, had the object been seen with the necessary degree of distinctness.

I have to regret that Sir HENRY ENGLEFIELD, who took a part in the former experiments, and whose assistance in making these would have been of material advantage, was unable to remain in town.

Finding from these experiments, that the change in the convexity of the cornea was not to be seen distinctly in the micrometer, it became an object to ascertain the degree of change which could in this way be distinctly determined.

For this purpose two mirrors were ground, and prepared in the same way as those used in the preceding experiment; their radii were exactly ascertained by measuring the tools in which they were finished off; the one was $\frac{4}{10}$ of an inch focus, the other $\frac{408}{1000}$; the difference between the size of the images reflected from their surface was just visible in the micrometer; and from their remaining fixed, the experiment could be made with every advantage; but it did not appear

probable that the same difference would have been visible had the mirror not been perfectly at rest. A smaller change could not therefore be detected in the eye; and when we consider the disadvantages under which an experiment of this nature must be made upon the human eye, from the unsteadiness of that organ, the short time it remains adjusted (a part of which is lost in bringing it within the focus of the microscope), and also from the motions of the head; it is not unreasonable to suppose that a change might take place in the cornea, to the same extent, without being distinctly seen.

To give an idea of the short time that a part can remain nicely adjusted by muscular action, I shall point out an experiment which any one may make upon himself: let him take a glass spirit level, and rest one end of it on a table, supporting the other with his hand, and endeavour to keep the air bubble in the middle; if the hand is very steady the bubble may be kept nearly in its place, but not exactly so, it will undulate, its motion corresponding with the actions of the muscles; making up for want of steadiness by short motions in contrary directions.

From these experiments the change in the curvature of the cornea could not be more than $\frac{1}{125}$ part of an inch, as any greater quantity would probably have been distinctly seen in the micrometer; this, however, is still more than was ascertained by our former experiments, which made it to exceed $\frac{1}{800}$ part of an inch.

This change in the cornea, on the first view of the subject, appeared sufficient to account for the adjustment of the eye, and when the lens is removed it probably may be sufficient; but the refractions at the cornea are so much changed by those at the

lens, as considerably to lessen their effect in fitting the eye for seeing near objects, and make this small increase of convexity inadequate to such an effect.

Finding this to be the case, it became necessary to examine the eye with attention, to see in what way the full effect was most likely to be produced. For this purpose the following experiments were made upon the human eye, to determine whether the axis of vision could be elongated by any uniform pressure applied to its coats.

The experiments were made in the following manner: an eye of a dead subject was carefully removed from the socket, before any change could be produced in consequence of death, and its different diameters were measured by a pair of calliper compasses. As soon as these were determined, a hole was made in the centre of the optic nerve, and a pipe fixed into it, through which air could be thrown into the cavity of the eye, so as to distend its coats. While distended in a moderate degree, by compressing with the hand a small bladder, containing air and quicksilver, attached to the pipe, the same diameters were measured again, and compared with those which were taken while in the natural state.

These experiments were made by Mr. MUTTLEBURY and Mr. WILLIAMS, two very intelligent and diligent students in surgery, who were filling situations that gave opportunity of making such experiments. They measured the diameters in these two states, and marked them on paper, without ascertaining their difference, so that there could be no fallacy in the measurement from any preconceived opinion; and I have every reason to believe there was none from inattention.

		Transverse diameter.	Axis from optic nerve.	Axis of vision.
		Twentieth parts of an inch.	Twentieth parts of an inch.	Twentieth parts of an inch.
The eye of a boy 6 years old, 45 minutes after death - - -	Natural state	17 $\frac{1}{2}$	17 $\frac{1}{2}$	17 $\frac{1}{2}$
	Distended state	17 $\frac{1}{4}$+	17 $\frac{1}{4}$+	18
The eye of a man 25 years old, 1 hour after death - -	Natural state	17 $\frac{3}{4}$	17 $\frac{3}{4}$	17
	Distended state	17 $\frac{1}{2}$	17 $\frac{1}{2}$	17 $\frac{1}{2}$
The eye of a man 50 years old, 20 minutes after death - -	Natural state	19	19	18 $\frac{1}{2}$
	Distended state	19	19	18 $\frac{1}{2}$

From these experiments it appears, that the diameters of the eye do not always bear the same proportion; sometimes the transverse diameter is the longest, in other eyes it is of the same length as the axis of vision; but when the coats are distended, the transverse diameter is diminished, and the axis of vision is lengthened.

This change, however, does not take place at all ages, for at 50 it was not met with.

In these experiments the pressure was made in the most unfavourable way for producing the greatest degree of elongation in the axis of vision; it was, however, the least exceptionable mode for ascertaining that such an effect could take place; when the pressure is made laterally and from without, the elongation must be still greater; and the action of the

straight muscles is the most advantageous that could be imagined for that purpose.

This lateral pressure will not only elongate the eye, and increase the convexity of the cornea, but it will produce an effect upon the crystalline lens and ciliary processes, pushing them forward in the same proportion as the cornea is stretched. This is necessary for two reasons; *viz.* to preserve the cavity containing the aqueous humour always of the same size, and to keep the cornea and lens at the same distance from each other. The ciliary processes, as they form a complete septum between the vitreous and aqueous humours, must be moved forward, together with the lens, when the cornea is rendered more convex, and when the cornea recovers itself they are thrown back into their former situation. In order to effect this with the nicety that is required, the ciliary processes are probably possessed of a muscular power.

That the ciliary processes are muscular is a very generally received opinion, and in the course of this lecture I shall adduce some facts in favour of it; they will also tend to confirm the opinion of these processes being a sling, in which the lens is suspended, and rendered capable of a small degree of motion.

The result of this inquiry, which has not been confined to the support of any particular theory, but carried on with the sole view of discovering the truth, appears to be, that the adjustment of the eye is produced by three different changes in that organ; an increase of curvature in the cornea, an elongation of the axis of vision, and a motion of the crystalline lens. These changes in a great measure depend upon the contraction of the four straight muscles of the eye.

Mr. RAMSDEN has been good enough to make a computa-

tion, by which the degree of adjustment produced by each of these changes may be ascertained. This he has promised to render more correct; and also to institute a series of experiments by which the effects of the motion of the lens may be more accurately determined. From Mr. RAMSDEN's computation, the increase of curvature of the cornea appears capable of producing one-third of the effect; and the change of place of the lens, and elongation of the axis of vision, sufficiently account for the other two-thirds of the quantity of adjustment necessary to make up the whole.

Having explained the mode by which the axis of vision can be elongated, and the convexity of the cornea increased, in the human eye, for the purpose of its adjustment, I was desirous of applying these observations to the eyes of other animals, that I might see whether their different structures would admit of the necessary changes, for producing an adjustment to different distances in the same way.

As many animals are known to have their vision distinct at very different distances, it appeared that much information might be gained by examining the structure of the eyes of those whose range of vision varies most from that of the human eye.

Quadrupeds in general must have their eyes fitted to see very near objects, as many of them collect their food with their mouths, in which action the objects are brought very close to the eye. Birds are under the same circumstances in a still greater degree with respect to their food; but from their mode of life, they also require the power of seeing objects at a great distance. Fishes, from the nature of the medium in which they live, must have some other mode of adjusting the eye,

than that of a change in the cornea, as that substance is possessed of the same refractive power with the surrounding fluid.

To avoid confusion in so extensive a field of inquiry, I shall separately consider the peculiarities in the eyes of these different classes of animals, so far as they appear to be concerned in producing the adjustment to different distances.

Quadrupeds have three modes of procuring their food; one by their fore-paws only, which they use like hands, as all the monkey tribe; the second, by their fore-paws and mouths, as the lion, and cat tribe; the third, by the mouth only, as all ruminating animals. These three different modes require the food being brought to different distances from the eye; and it is curious, that the muscles of the eye are different in all the three tribes.

In the monkey tribe, the muscles of the eye are exactly the same as in the human. In the lion tribe, they are double in number, and the four intermediate muscles are lost in the sclerotic coat, at a greater distance from the cornea than the others. In the ruminating tribe, there are four muscles, as in the human eye; but there is also a muscle surrounding the eyeball, attached to the bottom of the orbit, round the hole through which the optic nerve passes, and lost upon the sclerotic coat immediately before the broadest diameter of the globe of the eye; the upper portion of this muscle is rather the longest, its insertion being nearly in a circular line at right angles to the axis of vision, but not to the axis of the eye from the entrance of the optic nerve.

In quadrupeds in general, the ball of the eye is broader in proportion to its depth, than in the human subject; in the bull

the proportion is $1\frac{10}{16}$ inch to $1\frac{6}{16}$. The cornea is larger and more prominent; its real thickness is hardly to be determined, since, as well as that of the human eye, it readily imbibes moisture immediately after death. When dried, it is thinner than the sclerotic coat in the same state. In ruminating animals, it appears externally of an oval form; it is not, however, really so, the cornea itself being circular, as in other animals; but a portion of it is rendered opaque, by a membrane which covers its external surface, and produces an oval appearance. This circular form of cornea is necessary, that when it is stretched it may form a regular curve.

The ciliary processes, as in the human eye, are connected with the choroide coat; but they are larger, and are united at their origin with the iris.

This structure of the eye in quadrupeds, so far as it differs from that of the human eye, appears calculated to increase the power of adjusting it to see near objects, and from the mode of life which these animals pursue, such additional powers appear necesssary to enable them with ease to procure their food.

Birds in general procure their food by means of their beak; and the distance between the eye and the point of the beak is so small, that they must have a power of seeing very near objects. From living in air, and moving through it with great velocity, they require for their own defence, as well as to assist them in procuring food, a power of seeing at great distances.

That birds of prey see objects distinctly at a great distance appears to be proved by the following observations. In the year 1778, Mr. Baber and several other gentlemen were upon a hunting party in the island of Cassimbusar in Bengal, about

15 miles north of the city of Marshedabad; they killed a wild hog of an uncommon size, and left it upon the ground near their tent. About an hour after it was killed they were walking near the spot where it lay; the sky was perfectly clear, not a cloud to be seen, and a dark spot in the air at a great distance attracted their notice; it appeared gradually to increase in size, and moved directly towards them: as it advanced it proved to be a vulture, flying in a direct line to the dead animal, on which it alighted, and began to feed voraciously. In less than an hour, 70 other vultures came in all directions, some horizontally, but most of them from the upper regions of the air, in which a few minutes before nothing could be seen. Mr. BABER was so much struck with the circumstance at the moment, that he said to his friends, MILTON's poetical description of the vulture, being lured to its prey by the smell, would not apply to what they had just seen.

VOLNEY, in his travels through Egypt, mentions a circumstance somewhat similar. He says, "the conspicuous situa-
"tion of Aleppo brings numbers of birds thither, and affords
"the curious a very singular amusement: if you go after din-
"ner on the terraces of the houses, and make a motion as if
"throwing bread, numerous flocks of birds will fly instantly
"around you, though at first you cannot discover one; but
"they are floating aloft in the air, and descend in a moment to
"seize in their flight the morsels of bread which the inhabi-
"tants frequently amuse themselves with throwing to them."* This account of VOLNEY is confirmed by my friend Dr. RUSSEL, who has furnished me with an additional fact upon this sub-

* VOLNEY, English Translation, Vol. II. chap. 27, page 154.

ject. Dr. Russel says, that the relation of Volney is true; and that it is the amusement of the inhabitants, or rather of the Europeans, to allure birds by throwing up pieces of bread from the flat tops of the houses; these birds, to the best of his recollection, are the common gull (*larus canus* Linn.), which appear only at certain seasons.

But a fact more to the purpose of the present inquiry, is what Dr. Russel remembers often to have heard asserted by the European sportsmen at Aleppo, and indeed sometimes observed himself; namely, that in the most serene weather, when not a speck could be seen in the sky, nor any object discovered in the horizon of an extensive plain, a dog or other animal killed by accident, or shot, and left behind by the sportsmen as they traversed the country, in the space of a few minutes was surrounded by birds, before invisible, either of the vulture tribe or the sea eagles (*ossifragus* Linn.). Whether these birds by vision were directed to their prey, or allured by scent, he would not undertake to pronounce, but the phænomenon occasioned wonder; and the more so, as there was not time for putrefaction to take place, which might be supposed to diffuse scent to a great distance.

The eyes of birds are larger in proportion than those of any other animal, the eye of a thrush being equal to that of a rabbit. They are also broader in proportion to their depth than in the quadruped; and the cornea is more prominent.

The cornea is very thin when examined immediately after death, and is at that time more elastic than afterwards. In the goose, it was stretched so as to be elongated $\frac{2}{20}$ of an inch, but in an hour afterwards it had become thicker, and less elastic. The cornea is not united to the sclerotic coat by the

terminating of one abruptly in the other; but the two edges are bevilled off, and laid over each other for nearly one-tenth of an inch in the eye of the goose, and more where the eye is larger. In the recent state, the thin edge of the cornea is readily torn off from the inner surface of the sclerotic coat to which it adheres, so as to show this mode of union. This circumstance was known to HALLER, and is particularly described in his works.

There is a bony rim surrounding the basis of the cornea in the eyes of birds, which is peculiar to this class of animals. It is made up of a number of different parts, very commonly 13 in number; some of these are lapped over each other, but some have an irregular union, one part passing before, and the other behind the bony scale next to it. This bony circle, thus made up, is not equally broad in its different parts; it is broadest where it covers the upper and outer part of the eye, and narrowest where it covers the cornea towards the inner canthus.

This bony rim does not give an origin to the cornea, as might appear to a superficial observer, but is a bony hoop laid over the junction between the sclerotic coat and cornea; and as the thin edge of the cornea passes within the sclerotic coat, the principal attachment of the bony rim must be to that coat. The bony rim is adapted to the surface upon which it lies; the greatest part of its breadth is firmly connected to the sclerotic coat; and where the cornea projects, the anterior edge of the rim is turned forwards to correspond with that projection; here the scales are extremely thin, they terminate in a fine edge, and admit of being forced a little asunder, to adapt them to the stretched state of the cornea; but no such effect

can be produced upon the posterior part of the rim, the different parts being too firmly connected to admit of any separation.

The structure of this bony rim differs in different birds. In the goose and turkey the scales are thin and weak; in the cassuary they are thicker; and in the eagle they are very strong. In the owl, they put on a very different appearance; they are 15 in number, $\frac{6}{10}$ of an inch long, and instead of being lapped over one another, as in other birds, they are united by indented sutures; each portion is broadest next the sclerotic coat, and narrowest towards the cornea, giving the bony rim a conical form.*

This structure in the owl's eye differs from that in other birds, the anterior edge not admitting of being dilated to correspond with the change of figure in the cornea; this purpose in the owl is answered by a circular elastic ligament firmly attached to the anterior edge of the bony rim, and lying upon the outside of the basis of the cornea; there is a similar ligament in other birds, but less conspicuous.

This bony rim in the eyes of birds is particularly noticed by Haller; specimens of it, whole and in separate parts, are preserved in Mr. Hunter's collection; it has been also described by Mr. Smith, in a paper read before this Society: I shall, therefore, not dwell longer upon its structure, as it is not to my present purpose to take further notice of it than to explain its use respecting the adjustment of the eye, the subject of the present lecture.

The straight muscles of the eye in birds arise from the bottom of the bony orbit, as in the quadruped, and are firmly

* See the annexed plate.

attached to the posterior edge of the bony rim just described; they are four in number.

The ciliary processes are larger and longer in birds, than in other animals whose eyes are of the same size; they are evidently continued from the choroide coat, and adhere firmly to the capsula of the crystalline lens.

In the eyes of birds there is a substance which is peculiar to that class of animals, called the marsupium. It is a process composed of a corrugated vascular membrane attached to the centre of the retina, where the optic nerve terminates. Its origin is in a straight line, extending from the termination of the optic nerve to the lower part of the eye; in the turkey $\frac{5}{20}$ of an inch in length, and connected with the bottom of the eye by an elastic ligament about $\frac{1}{40}$ of an inch thick. The number of folds of which it is composed varies in different birds, from 5 to 15, or more; they are all of the same length, which in the turkey is about $\frac{4}{20}$ of an inch; they are covered with the nigrum pigmentum, and are attached anteriorly to the capsula of the crystalline lens, either immediately, as in the goose, or by intermediate membrane, as in the turkey.*

The structure of the marsupium is very similar to that of the ciliary processes, but stronger in all its parts, and like them it has a connection with the crystalline lens.

The connection between the marsupium and lens, in a natural state of the parts, is from its transparency invisible; but in the goose and cassuary, where the marsupium extends to the capsula of the lens, if the parts are coagulated in spirits, it becomes very apparent, and in these birds such a connection is generally allowed. In other birds, it is doubted by some, and

* *Vide* plate.

denied by others, who have written upon the subject. HALLER has taken some pains upon this point: he found, that by pulling the marsupium the motion was communicated to the lens, but he was unable to make out the mode of union; and all his attempts to coagulate the cells of the vitreous humour were unsuccessful; he says, no spirits can produce such a change. I have found, however, that, after the eye has remained a few days in rectified spirits, the medium between the marsupium and lens is coagulated, and rendered visible. By this means I have detected it in the turkey's eye; it is connected to the whole anterior extremity of the marsupium, extends to the capsula of the lens, aud appears to be about one half the length of the marsupium itself.

The union has been supposed to be extremely weak, because after death it readily gives way; this, however, is by no means the case, for when it is coagulated in rectified spirits, it is not easily torn; and the reason of its giving way in the dead eye, is probably from dissolution readily taking place when surrounded by moisture.

The anterior edge of the marsupium in some birds is narrower than its base, as in the cassuary; in others, it is of the same extent, as in the turkey; and in all, I believe, it is an uniform line; but when it is separated from the lens the folds contract irregularly, and appear of different lengths. In the eagle the marsupium is uncommonly strong.

From the similarity of structure in the marsupium and ciliary processes, as also their connection with the crystalline lens, I was desirous of ascertaining whether the marsupium was possessed of any muscular power, as this would determine

the same point with respect to the ciliary processes, and might lead to an explanation of the use of both these parts.

With this view I made the following experiments. The marsupium and crystalline lens of a goose's eye were exposed immediately after death; and the lens was pushed forwards, by which means the marsupium was elongated, and measured $\frac{5}{20}$ of an inch; upon taking off the pressure, it again contracted to $\frac{7}{40}$; this was repeated several times. The parts were then left, till it was supposed that all remains of life were gone, and the same experiment was repeated. In the stretched state it measured as before, $\frac{5}{20}$ of an inch, but in the contracted state, $\frac{4}{20}$; this change arose from the elasticity of the ligament connecting the marsupium to the bottom of the eye; and therefore the contraction of $\frac{3}{40}$, which was now lost, must have arisen from some other cause.

The result of this experiment favours the idea, that the marsupium possesses a muscular power, but in matters where we are so liable to be deceived, it seemed not a sufficient proof; I therefore made several other experiments, but they were all liable to some objections; the following, however, appears satisfactory, and shows that there is a power of contraction in the marsupium independent of elasticity.

The crystalline lens of a turkey's eye was extracted, and immediately afterwards the turkey was killed, by wounding the spinal marrow; the two eyes were taken out, and put into spirits.* In the one, the marsupium had nothing to pre-

* In the act of dying, the muscles are found to contract to their utmost, where there is no resistance to prevent such action; this is also found to take place in the greatest degree, when the animal is killed by any violence committed upon the brain, or spinal marrow.

vent its contracting to the utmost; while in the other, the lens being in its natural situation, could not allow of any unusual contraction. Some days after, the two eyes were examined; in the perfect eye the marsupium measured $\frac{4}{20}$ of an inch, and the different folds of it were semitransparent; in the imperfect eye the marsupium measured $\frac{3}{20}$ of an inch, and the folds were much more opaque. Here, then, was a difference of $\frac{1}{20}$ of an inch in the length of the two marsupia; which could arise from no other cause than the one having contracted so much more than the other, which contraction we must consider as muscular.

HALLER denies the marsupium to be muscular, because there is no such appearance in its structure. My own opinions upon the structure of muscles have been already explained to this learned Society; and I have lately met with an observation in LYONET's dissection of a caterpillar which tends to confirm them. He says, the muscles of the caterpillar are, in their natural state, transparent as jelly, and have vessels passing through their substance in every direction, which afford to the eye of the observer in the microscope the most beautiful appearance of a congeries of vessels.*

The peculiarities in the bird's eye are such as tend to facilitate both the lengthening of the axis of vision, and increasing the convexity of the cornea.

* "Les muscles des chenilles, dans leur état naturel, ils sont mous, ils prêtent extrêmement, ils ont la transparence d'une gelée, ils sont d'un gris bleuâtre, et les bronches argentées, ou vaisseaux aëriens, qu'on voit alors distinctement ramper par dessus, et penetrer dans toute leur substance, offrent à la loupe un spectacle qu'on ne se lasse point d'admirer."—*Traité Anatomique de la Chenille, par* PIERRE LYONET, chap. 6, page 92.

The bony rim, to which the muscles are attached, confines the effect of their pressure to the broadest part of the eye; and as their action throws forwards the cornea, the anterior edge of the bony rim yields, to adapt itself to that change; the ciliary processes are long, to admit of the lens being moved forwards, and by their action bring it back to its place; by these means the eyes of birds are adjusted to see very near objects with more facility than the eyes of other animals.

As the eyes of birds are likewise to be adjusted to see very distant objects, the marsupium is placed behind the crystalline lens, to draw it backwards, and when it acts, part of the pressure from behind being removed, the cornea is rendered flatter; and the anterior edge of the bony rim is adapted to it, in this state, by the contraction of the annular elastic ligament.

It may be said, that to see with parallel rays no such great change is necessary; it must, however, be considered that where vision is to be very distinct, a certain nicety of adjustment becomes necessary, and the action of the marsupium is probably intended for that purpose.

In the bird (although not immediately connected with the present subject) there is one of the most beautiful illustrations of the combination of muscular and elastic substances. This is employed for the motion of the membrana nictitans, and as it shews that such a combination is adopted wherever it can be used with advantage, and is provided as a defence for the organ in which I am endeavouring to explain such a combination, I cannot avoid taking notice of it. The membrana nictitans is composed of an elastic membrane, which is connected by means of a tendon, with two muscles situated

upon the posterior part of the eyeball; the action of these muscles brings the membrane over the cornea, and the instant they cease to contract, the elasticity of the membrane draws it back again.

The eyes of fishes have several peculiarities, and in many respects their structure differs from that which is observed in the quadruped and bird.

The muscles of the eye, that correspond to the straight muscles in the quadruped, are four in number, they are, however, differently placed; they do not surround the eyeball; but two of them are on that side of the orbit next to the nose of the fish, the other two on the opposite side; their attachment to the eye is close to the edge of the cornea; they do not, however, pass round the eyeball towards the posterior part, as in other animals, but are connected with the bones of the head at some distance from the eye on each side; so that they cannot at all compress the eye laterally, they can only pull it backwards by the combined effect of their action.

The bottom of the orbit on which the eyeball rests, is solid, and adapted to it, there being no fat interposed between them as in other animals; and where the eye is removed to a great distance from the skull, and that cannot be the case, there is a strong cartilage projecting from the skull to the bottom of the eye, and that end of it next to the eye is concave, and fitted to the portion of the eyeball directly opposite the cornea, just above the entrance of the optic nerve. This is considered as a fixed point upon which the eye moves, but it will also, from the situation of the muscles, allow the eye to be forced back upon it, and the whole eye to be flattened.

The shape of the eye differs considerably in different fishes,

but in all of them the transverse diameter is the longest. In the haddock, the proportion is $\frac{11}{10}$ths to $\frac{8}{10}$ths of an inch, and in some fishes it differs much more.

The size of the eye does not correspond with that of the fish; the salmon's eye being smaller than the haddock's.

The sclerotic coat is in some fishes membranous;* in some partly bone,† in others entirely so,‡ but in general the posterior part is membranous, although the lateral parts are bone.§

The cornea is in general flat, not always circular in its shape, is very thin, made up of laminæ, and does not lose its transparency in spirits, appearing like talc.|| In others it is more convex, as in fish of prey; this appears to adapt it to the spherical crystalline lens, which in them lies directly behind it.** The tunica conjunctiva forms the anterior layer of the cornea,†† and in some fishes is quite detached.

In the eel there is a transparent horny convex covering, at some distance before the eye, to defend it from external accidents. This covering, to an eye fitted to see in air, would entirely take off the effects arising from change of figure in the cornea; but in water, where no such change could be attended with advantage, such a covering is employed as an external defence.

In the eyes of fishes, the ciliary processes are entirely wanting. The crystalline lens is spherical, and imbedded in the vitreous humour, which is inclosed in cells of a stronger texture than in other animals.

The iris does not admit of motion; this is taken notice of by

* Haddock. † Sword-fish. ‡ Devil fish. § Mackerel.
|| Sword-fish. ** Pike. †† Haddock.

HALLER; and the reason probably is, that the light in water is never too strong for the eye to bear.

There is a muscle situated between the retina and the sclerotic coat, which is, I believe, common to all fish. This muscle is particularly described by HALLER; and its use is stated to be that of bringing the retina nearer the crystalline lens, for the purpose of seeing objects at a greater distance. Mr. HUNTER called it the choroide muscle, and has preserved several preparations of it.

This muscle has a tendinous centre round the optic nerve, at which part it is attached to the sclerotic coat; the muscular fibres are short, and go off from the central tendon in all directions; the shape of the muscle is nearly that of a horse-shoe; anteriorly it is attached to the choroide coat, and by means of that to the sclerotic. Its action tends evidently to bring the retina forwards; and in general, the optic nerve in fishes makes a bend where it enters the eye, to admit of this motion without the nerve being stretched.

In those fishes that have the sclerotic coat completely covered with bone, the whole adjustment to great distances must be produced by the action of the choroide muscle; but in the others, which are by far the greater number, this effect will be much assisted by the action of the straight muscles pulling the eyeball against the socket, and compressing the posterior part; which, as it is the only membranous part in many fishes, would appear to be formed so for that purpose.

In fishes, the eye in its natural easy state appears to be adjusted to near objects, requiring some change to adapt it to see distant ones; in this respect differing entirely from the bird, the quadruped, and the human.

As the change which the eye is to undergo is different, so are the parts which produce it. The cornea, in many fishes, is neither circular, prominent, nor elastic, and the ciliary processes are wanting. The straight muscles pass off in different directions, to prevent the eye from being pressed upon laterally; the coats of the eye at that part are bony, in some fishes, to prevent the same effect; and the bottom of the orbit, which in other animals is filled with fat and loose cellular membrane, has no such covering, but is a hard concave surface, to give resistance, and assist in flattening the eye.

From the preceding observations, deduced from the structure of the eye in different animals, it appears that there are two modes of adjusting the eye, one for seeing in air, the other for seeing in water; and it is probably the want of this knowledge that has misled former inquirers, by confining their researches to the discovery of some one principle common to the eyes of all animals.

The crystalline lens, as the most conspicuous part, engrossed their whole attention, and they did not think any of the others capable of giving material assistance in producing so curious an effect.

The ciliary processes, from their connection with the lens, were by some believed capable of bringing it forwards; by others they were supposed to contract, and by that action elongate the eye, and remove the lens further from the retina: but these processes could never bring the lens forwards, unless the cornea was also moved forwards; for the lens and processes forming a complete septum, the aqueous humour would prevent the lens from making any advance in that direction: and the processes themselves are neither strong enough in

their muscular power, nor sufficiently attached to the coats of the eye, to alter its form by their contraction. In birds likewise, the bony rim renders this impossible.

That the axis of vision is really lengthened, and the lens moved forwards, for the purpose of adjusting the eye to see near objects, is rendered highly probable, since all the facts I have been able to collect seem to point out these changes; nor can the action of the external muscles increase the curvature of the cornea without producing them.

If the axis of vision being lengthened was believed by some physiologists to produce the whole adjustment of the eye to see near objects; if the crystalline lens being moved forwards was supposed by others to do the same thing; and if the cornea being rendered more convex appeared at the first view equally to account for it; all the three, when combined for that purpose, must undoubtedly be considered as sufficient to produce the effect.

EXPLANATION OF THE PLATE. (Tab. I.)

Fig. 1. A side view of the cornea of the eye of a goose, to show the bony rim, and elastic annular ligament, in their natural situation; *a* the bony rim; *b* the elastic ligament.

Fig. 2. A view of the same parts, in the eye of the great horned owl, to show the difference of structure; taken from a dried preparation in Mr. HUNTER's collection.*

* Since this lecture was read before the Royal Society, Sir JOSEPH BANKS has put into my hands a paper upon the anatomical structure of the eye, in which there is a plate, containing four views of the bony rim in the owl's eye. The parts they re-

Fig. 3. The marsupium in the eye of the turkey, attached to the bottom of the eye, and connected by a transparent membranous union with the crystalline lens; made visible by coagulation in rectified spirits.

Fig. 4. The marsupium in the eye of the emeu, from New South Wales, with a portion of the membrane that connects it to the lens; the marsupium is drawn together at that end next the lens, giving it the appearance of a purse, from which it probably got the name marsupium.

Fig. 5. and 6. Two views of the crystalline lens of the eye of a goose, to show the attachment of the marsupium to the lens.

These different drawings are of the natural size of the parts they represent.

present are exactly similar to those shown in the second figure; and had the paper been published in this country, would have rendered it unnecessary.

The paper is intituled *Esposizione Anatomica delle parti relative all' Encefalo degli Uccelli, del Sig.* VINCENZO MALACARNE; it is published in the Italian Transactions, called *Memorie di Matematica e Fisica della Società Italiana,* Tomo VII. Verona, 1794.

Fig: 1.

Fig: 2.

Fig: 3.

Fig: 4.

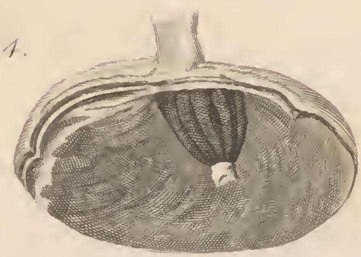

Fig: 5.

Fig: 6.